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This handbook for the port of Nice, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

11. NICE

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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (CNOC) requirements validated by the Chief of Naval Operations (CNO).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to NOCC, Rota with a copy to the geophysical officer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

M. G. SALINAS
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
	BARCELONA, SPAIN
	PALMA, SPAIN
	IBIZA, SPAIN
	POLLENSA BAY, SPAIN
	VALENCIA, SPAIN
	CARTAGENA, SPAIN
	GENOA, ITALY
	LIVORNO, ITALY
	SAN REMO, ITALY
	LA SPEZIA, ITALY
	VENICE, ITALY
	TRIESTE, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

Nice is located on the south coast of France in the region known as the French Riviera (Figure 2-1), about 12 n mi west of the Italian border. High mountains back the coastline north of Nice.

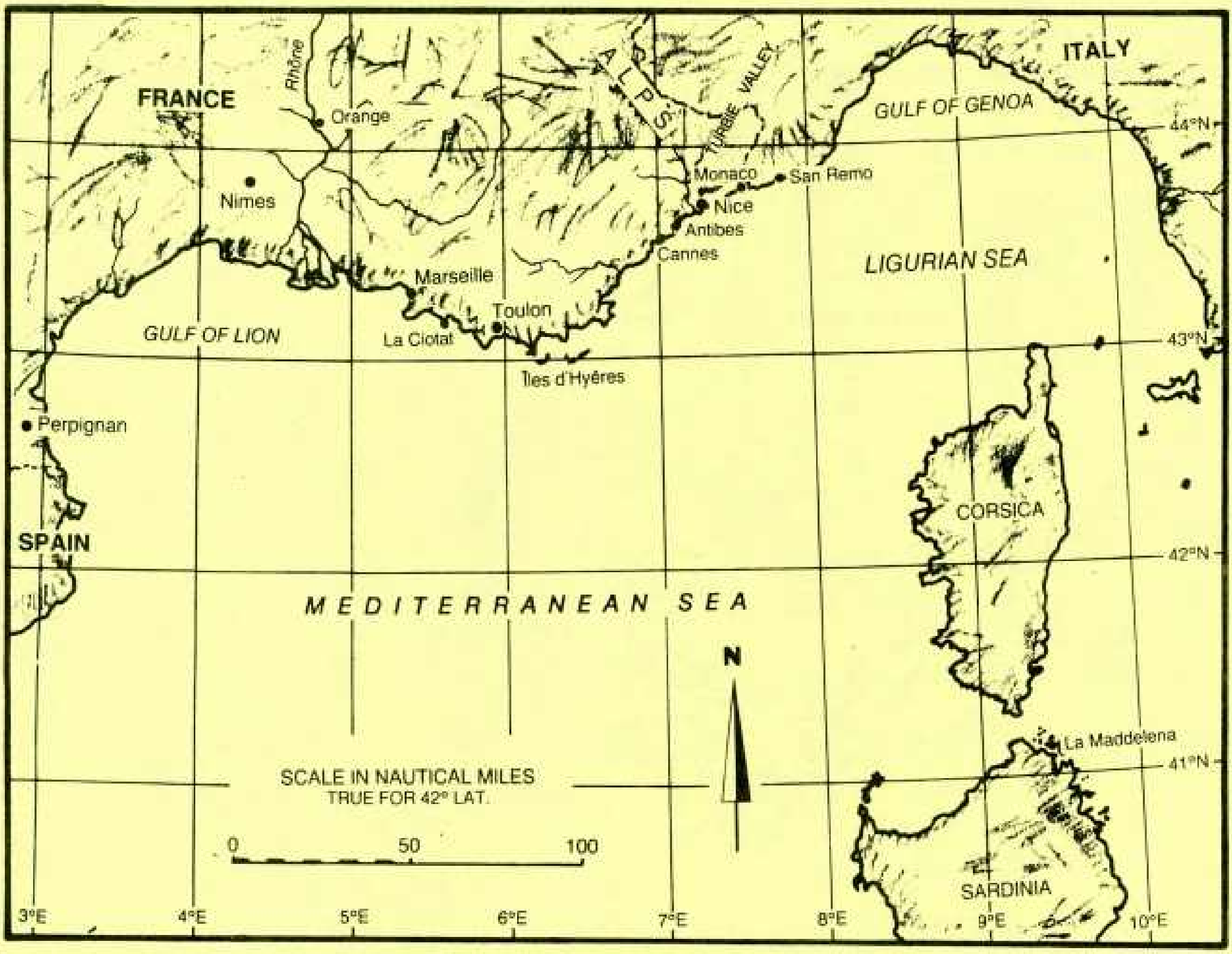

Figure 2-1. The Northwestern Mediterranean Sea.

The Port of Nice is located about 1 n mi west of the Bay of Villefranche between Cap de Nice on the east and Pointe Rouba-Capeou. Cap de Nice is the southwestern extremity of Mount Boron, which has elevations of 722 ft (220 m) and 591 ft (180 m) located about 3/4 n mi northeast and southeast of the Port respectively (Figure 2-2).

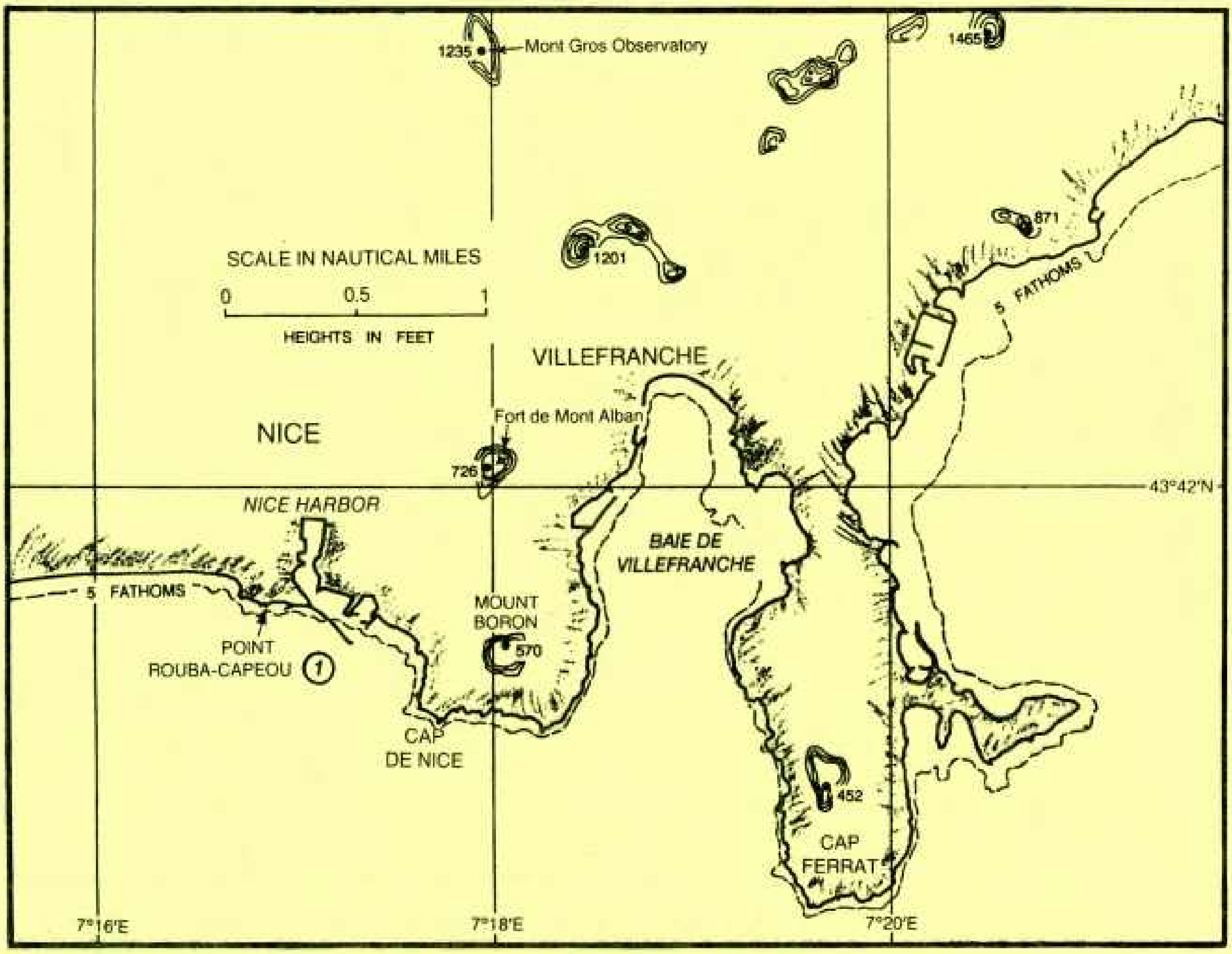

Figure 2-2. Approaches to the Port of Nice.

The inner harbor of the Port of Nice is comprised of 4 primary basins and is capable of accommodating vessels up to 450 ft (137 m) in length with drafts not exceeding 21 ft (6.4 m) (Figure 2-3). The anchorage is located outside the protective breakwaters (Figure 2-2). Bottom type and holding qualities are not specified.

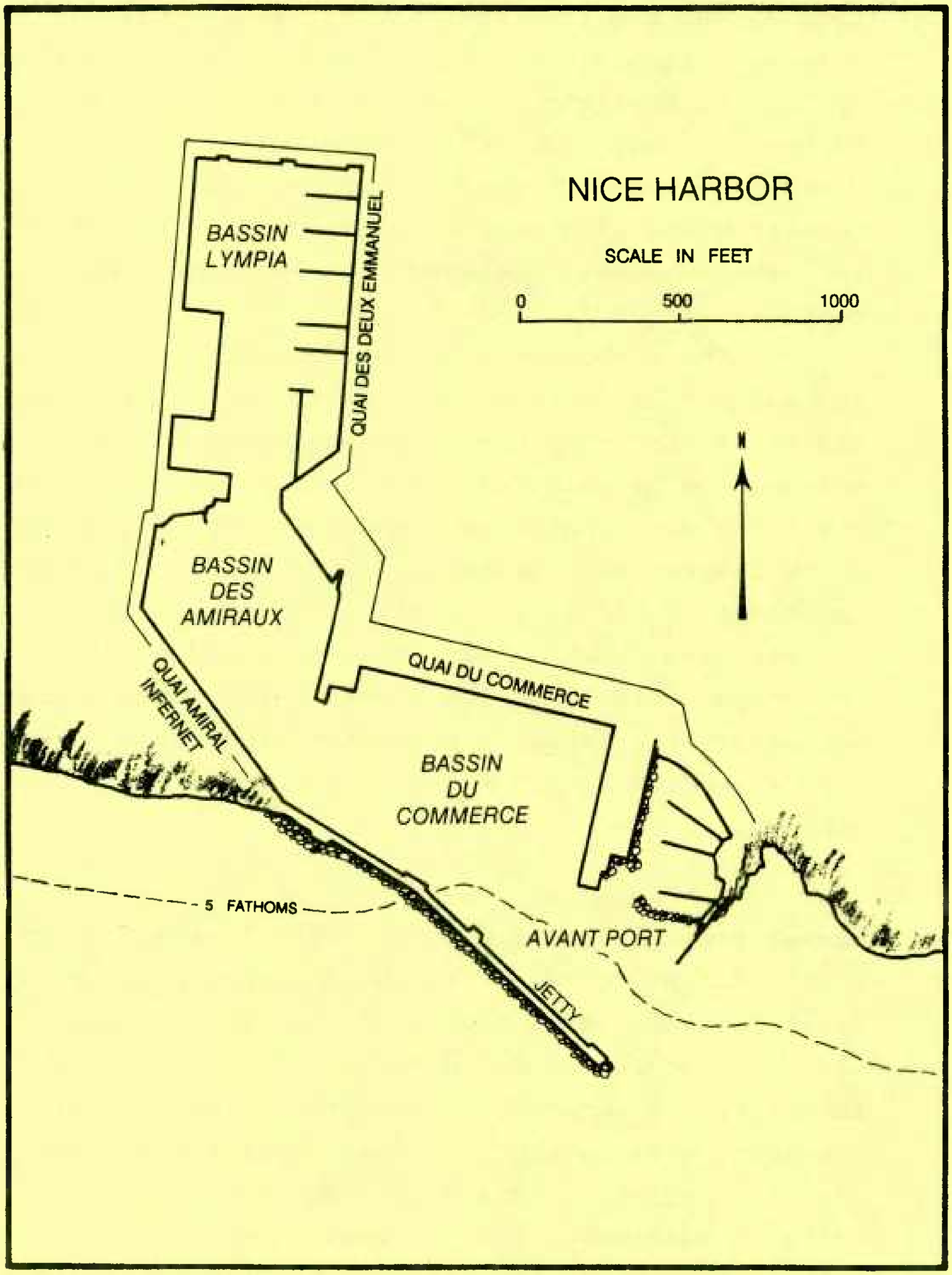

Figure 2-3. Nice Harbor.

The inner harbor of the Port of Nice is well protected from the effects of most sea and swell waves. The southeast facing harbor entrance does allow waves from the southeast quadrant to pass through, thereby subjecting vessels moored in parts of the two outermost basins, Avant Port and Bassin du Commerce, to wave motion. Ships moored in Bassin des Amiraux and Bassin Lympia, the two innermost basins, experience little or no motion. High winds at Nice are infrequent and normally do not necessitate a sortie from the inner harbor. Secure moorage may require a doubling of mooring lines. South and southwest winds are rare, but they sometimes blow in gusts with rain squalls and create a strong swell in the channel, making the entrance difficult to navigate.

The anchorage, located outside the inner harbor, is subject to winds and waves from east-southeast clockwise through west-southwest. Consequently, it is seldom used by ships of the U.S. Navy because they prefer using the more protected anchorage at the adjacent Port of Villefranche. Westerly Mistral winds along the coast can cause 6 ft (2 m) swell and 40 kt winds at the Villefranche anchorage, but conditions at the Nice anchorage would likely be worse. Also, the Villefranche anchorage is largely protected from east to southeast wind and waves by Cap Ferrat, but the Nice anchorage is exposed.

Currents at the Port of Nice are negligible. Normal tidal range is slight, with a variation of about 1 ft (0.3 m) common. In Nice harbor however, the sea level can vary as much as 3 ft (0.9 m), depending on the wind. According to Hydrographer of the Navy (1965), the lowest levels occur in February, slowly rising until December, after which the water level falls abruptly.

Specific hazardous environmental conditions, vessel situations, and suggested precautionary/evasion action scenarios for the Port of Nice are summarized in Table 2-1.

Table 2-1. Summary of hazardous environmental conditions for the Port of Nice, France.

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
1. E-SE'ly winds/waves - Worst weather condition at Nice. * Swell enters southeast facing entrance to inner harbor. * Most common in winter and early spring. * Usually accompanied by cloudy, rainy weather.	Advance warning * Strong or strengthening high pressure cell over central Europe with low pressure south or southwest of Nice.	(1) Moored - inner harbor.	(a) Vessels moored near harbor entrance may move excessively or shift at their berths. * Additional mooring lines or doubling of existing lines may be required. (b) Be aware of wind chill factor.
		(2) Anchored.	(a) A strong event may expose vessels to heavy weather conditions. * Deployment of 2 anchors may be required. * Moving to the more protected, adjacent roadstead at Villefranche is recommended. (b) Be aware of wind chill factor.
		(3) Arriving/departing.	(a) Incoming vessels should be aware of possible conditions in inner harbor and roadstead. * Diverting to more protected, adjacent Port of Villefranche should be considered. (b) Be aware of wind chill factor.
		(4) Small boats.	(a) Swell entering harbor entrance may preclude safe small boat passage. * Small boat runs to/from anchorage may be curtailed until conditions abate. (b) Be aware of wind chill factor.
2. S-SW'ly winds/waves - Occurs infrequently. * Most common in winter and early spring. * May result in swell to 10 ft (3 m) in coastal waters. * Wind and swell directions may differ.	Advance warning * The early stages of cyclogenesis south of the Alps commonly result in SW'ly 30-40 kt winds in the region between the French coast and Corsica * Easterly moving depressions moving into Ligurian Sea or across Corsica into Italy. Duration * Swell may persist for 2-3 days.	(1) Anchored.	(a) A strong event may expose vessels to heavy weather conditions. * Deployment of 2 anchors may be required. * Moving to a more protected anchorage, such as Toulon, should be considered.
		(2) Arriving/departing.	(a) Heavy weather conditions may create hazardous conditions for incoming and outgoing vessels. * SW'ly swell creates difficult navigation situation in channel to harbor entrance. * Possibility of wind and swell being from different directions makes anchored vessels liable to rolling. * Delaying arrival until after conditions abate should be considered.
		(3) Small boats.	(a) Wind and/or swell outside harbor entrance may create hazardous small boat operating conditions. * Inner harbor operations largely unaffected.
3. Mistral winds/waves - Strong W to NW'ly wind. * SW'ly swell to 6 ft may accompany W-NW'ly wind to 40 kt. * Strongest and most common in late winter and early spring but may occur anytime. * Impact on surface normally limited to waters 2-3 n mi or more south of the coast but may be felt at anchorage. * Wind shear may develop at 600-1000 ft (183-305 m) altitude over airport.	Advance warning * Mistral will start west of Nice when the following pressure differences are achieved--highest pressure to west. * Perpignan - Marseille, 3 mb. * Marignane - Nice, 3 mb. * Perpignan - Nice, 6 mb. * Conditions favorable for Genoa low formation are conducive to the start of a Mistral at Marseille. * For Mistral winds to affect the Nice area, they will first be observed at Marseille/Toulon. * Mistral will spread east to Nice area if a 10 mb pressure difference exists between Toulon and Nice. * With only 2 mb difference between Marseille and Toulon the Mistral will stop near Toulon.	(1) Anchored.	(a) Vessels in anchorage should experience only minor problems. * Two anchors may be required. * Moving to Villefranche may be preferable alternative to remaining at Nice. Buoy 3 at Villefranche should afford better protection from wind, but seaward (aircraft carrier) anchorage at Villefranche will likely experience the same conditions as Nice.
		(2) Arriving/departing.	(a) Conditions nearshore may differ markedly from those existing only 2-3 n mi offshore. * Offshore winds may be W'ly 40 kt while the Port of Nice enjoys light E'ly winds.
		(3) Small boats.	(a) Small boat runs to/from the anchorage may be curtailed until conditions abate if winds are blowing at anchorage position. * Inner harbor is largely unaffected.
		(4) Aircraft operations	(a) Flight operations at or near the Nice airport may be hazardous. * Landing aircraft are most susceptible to dangerous conditions. * Aircraft may experience severe/extreme turbulence in the lower levels of the atmosphere. * Only critically urgent flights should be conducted, and those only after flight crews are fully briefed on potential wind shear.

SEASONAL SUMMARY OF HAZARDOUS WEATHER CONDITIONS

The inner harbor of the port of Nice is basically protected from most hazardous wind and wave conditions. The anchorage, however, is outside these protective confines and is vulnerable.

WINTER (November thru February):

* Mistral winds (usually westerly) normally not more than 25 kt in harbor but can be 40 kt at anchorage.
* On occasion, northerly Mistrals reach Nice not on surface but aloft, causing hazardous wind shear for aircraft operations.
* Waves can penetrate the harbor from the east. Some berths near the entrance and boating will be affected.

SPRING (March thru May):

* Early spring similar to winter. Mistral events are rare by season's end.

SUMMER (June thru September):

* Relatively uneventful.

AUTUMN (October):

* Short transition season as winter-like weather returns by end of month.

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

REFERENCES

Hydrographer of the Navy, 1965: Mediterranean Pilot, Volume II. Published by the Hydrographer of the Navy, London, England.

3. GENERAL INFORMATION

This section is intended for Fleet meteorologists/oceanographers and staff planners. Paragraph 3.5 provides a general discussion of hazards and Table 3-2 provides a summary of vessel locations/situations, potential hazards, effects-precautionary/evasive actions, and advance indicators and other information about the potential hazards by season.

3.1 Geographic Location

Nice (Figure 3-1), is located on the southern coast of France in the region known as the French Riviera approximately 12 n mi west of the Italian border. High mountains back the coastline north of Nice.

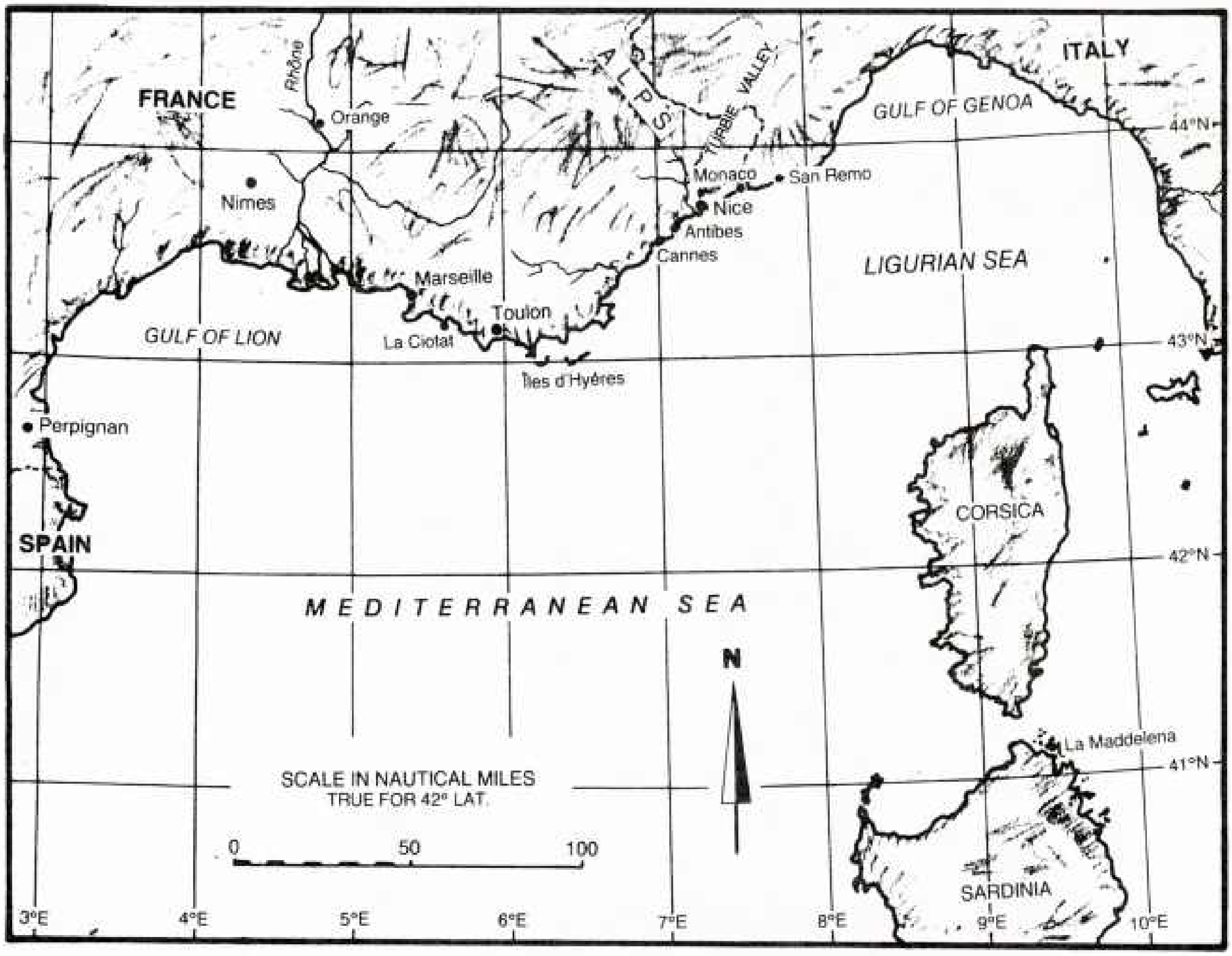

Figure 3-1. The Northwestern Mediterranean Sea.

The Port of Nice (Figure 3-2), is located about 1 n mi west of the Bay of Villefranche between Cap de Nice on the east and Pointe Rouba-Capeou. Cap de Nice is the south-western extremity of Mount Boron, which has elevations of 722 ft (220 m) and 591 ft (180 m) located about 3/4 n mi northeast and southeast of the Port respectively.

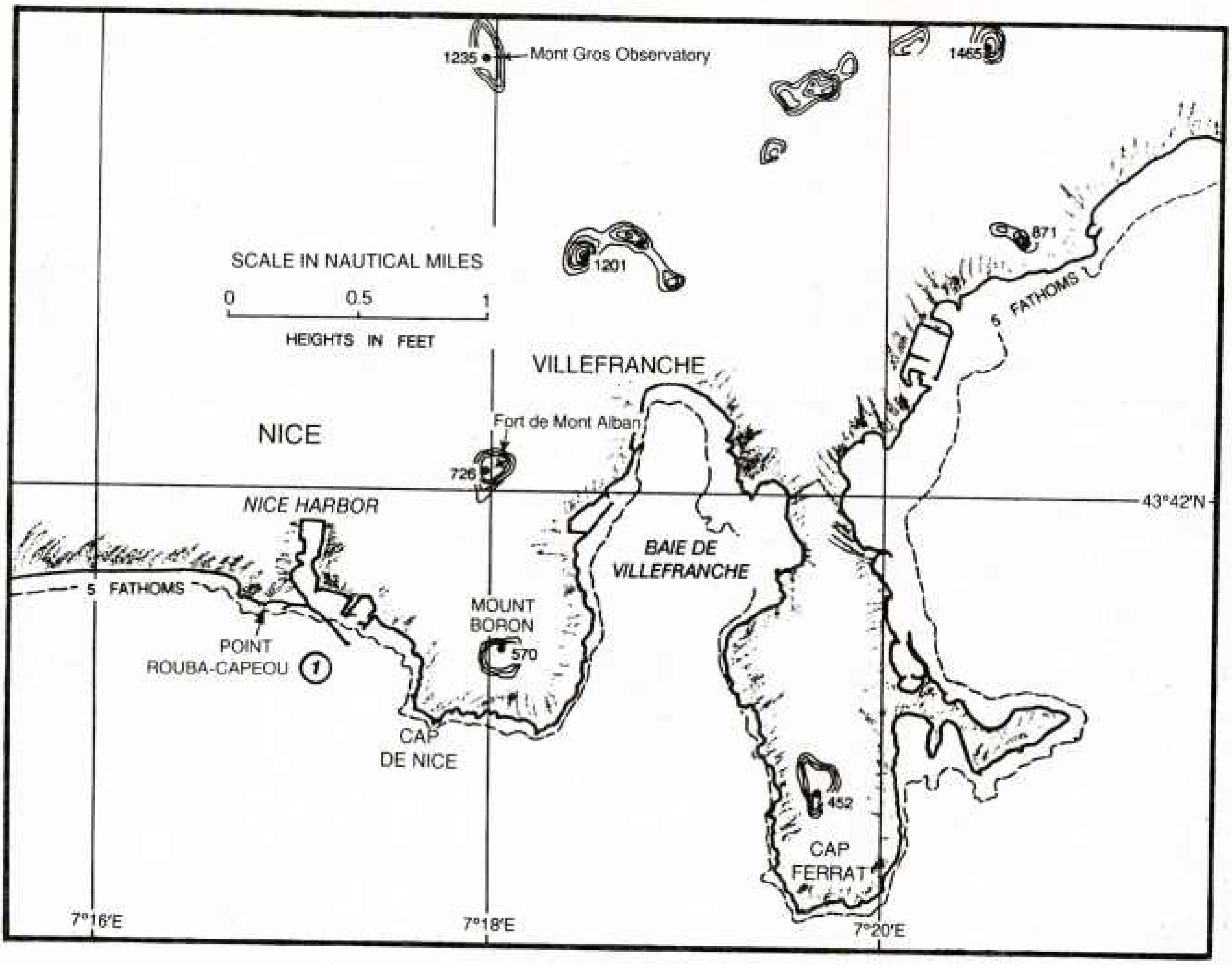

Figure 3-2. Approaches to the Port of Nice.

The entrance to the Port of Nice (Figure 3-3), is open to the southeast, passing between the head of a long jetty on the south, and a ridge of rocks which extends southwestward from the northeastern side of the harbor. The harbor is comprised of 4 primary basins, and can accommodate vessels to 443 ft (135 m) with maximum drafts of 21 ft (6.4 m) (Hydrographer of the Navy, 1965 and FICEURLANT, 1984). Prominent landmarks include Le Chăteau, a distinctive wooded hill on the southeastern end of the town of Nice just west of the harbor, a cupola of the Mont Gros Observatory which is located on the summit of Mount Gros about 2 mi north of Le Chăteau, and Fort de Mont Alban, situated on the summit of Mount Alban northeast of Nice.

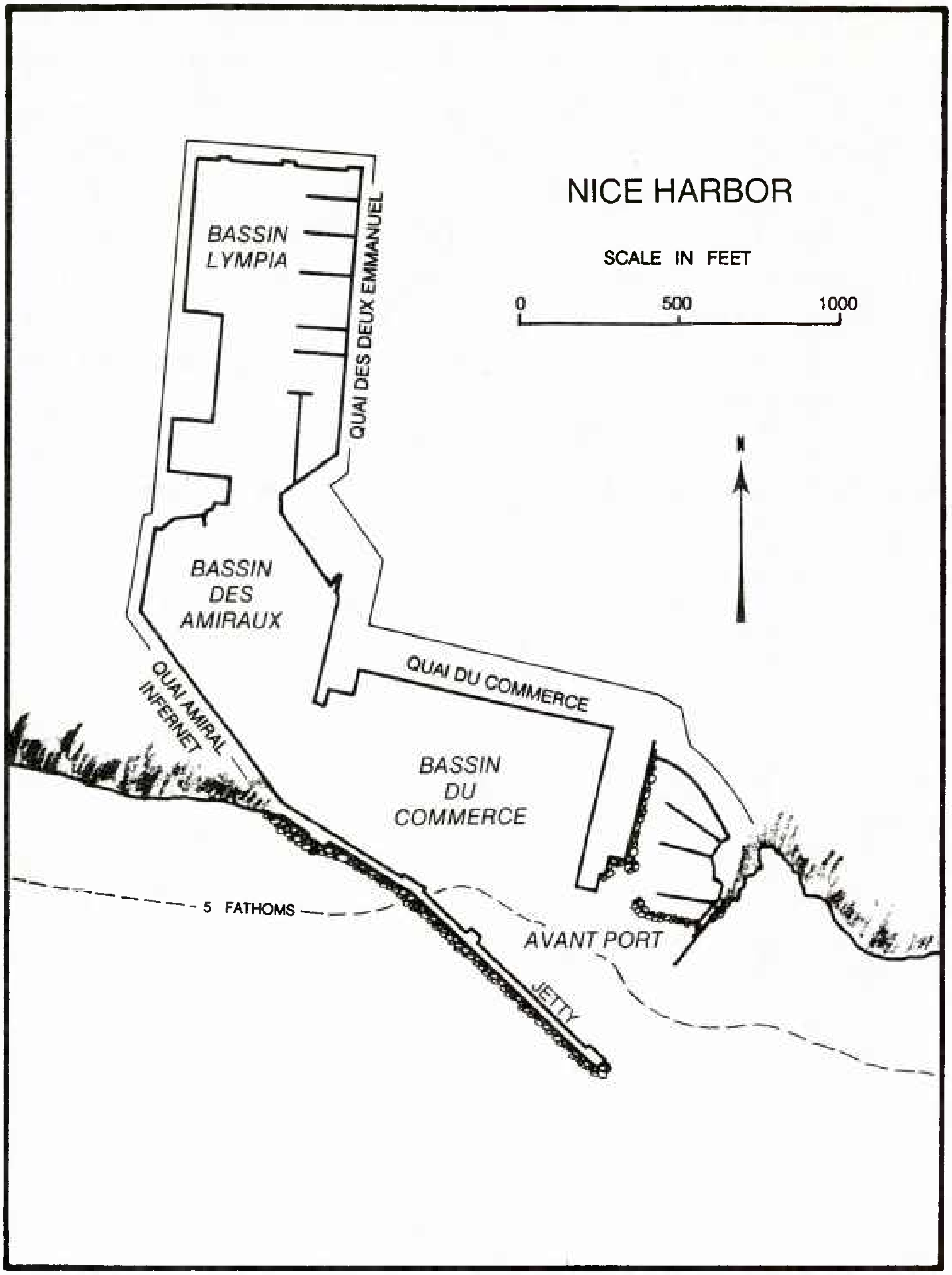

Figure 3-3. Nice Harbor.

3.2 Qualitative Evaluation of the Port of Nice

The inner harbor of the Port of Nice is well protected from the effects of most sea and swell waves. The southeast facing harbor entrance does allow waves from the southeast quadrant to pass through, thereby subjecting vessels moored in parts of the two outermost basins, Avant Port and Bassin du Commerce, to wave motion. Ships moored in Bassin des Amiraux and Bassin Lympia, the two innermost basins, experience little or no motion. High winds at Nice are infrequent and normally do not necessitate a sortie from the inner harbor. Secure moorage may require a doubling of mooring lines. South and southwest winds are rare, but they sometimes blow in gusts with rain squalls and create a strong swell in the channel, making the entrance difficult to navigate.

The anchorage, located outside the inner harbor, is subject to winds and waves from east-southeast clockwise through west-southwest. Consequently, it is seldom used by ships of the U.S. Navy because they prefer using the more protected anchorage at the adjacent Port of Villefranche. Westerly Mistral winds along the coast can cause 6 ft (2 m) swell and 40 kt winds at the Villefranche anchorage, but conditions at the Nice anchorage would likely be worse. Also, the Villefranche anchorage is largely protected from east to southeast wind and waves by Cap Ferrat, but the Nice anchorage is exposed.

3.3 Currents and Tides

Currents at the Port of Nice are negligible. Normal tidal range is slight, with a variation of about 1 ft (0.3 m) common. In Nice Harbor however, the sea level can vary as much as 3 ft (0.9 m), depending on the wind. According to Hydrographer of the Navy (1965), the lowest levels occur in February, slowly rising until December, after which the water level falls abruptly.

3.4 Visibility

Visibility restriction is not a significant problem at Nice. Records for the airport at Nice show that visibility reduces below 0.6 mi (1 km) about once per month during the period September through February, twice during March, April, and June, and three times in May. July and August are usually void of any significant visibility restrictions.

3.5 Hazardous Conditions

The inner harbor of the Port of Nice has only limited exposure to most hazardous wind and wave conditions, but the anchorage, which is outside the protective confines of the inner harbor, is exposed and vulnerable to the same conditions. The position of the Port near the eastern limit of the area affected by Mistral winds and the configuration of the adjacent landmass minimizes the impact of the Mistral.

Although rare, storms having tropical cyclone characteristics with fully developed eyes have been observed on at least three occasions in the Mediterranean Basin: 23-26 September 1969, 22-28 January 1982, and 26-30 September 1983. On the latter occasion the storm moved northwest from the Gulf of Gabes (on the southeast coast of Tunisia), through the Straits of Sicily, along the east coast of Sardinia, and into the Gulf of Genoa. Winds of 100 kt were observed near the eye while Cagliari, Sardinia reported winds of 60 kt. While the probability of such a storm striking Nice is very slight, the meteorologist must be aware of the possibility.

Nice transmits weather forecasts via VHF Channel 16 (primary) and Channel 12 (secondary).

A seasonal summary of various known environmental hazards that may be encountered in the Port of Nice follows.

A. Winter (November through February)

Winter brings unsettled weather to Nice. Gusty winds are common, but gales (≥34 kt) are rare. The proximity of Nice to the Gulf of Genoa, one of the most active regions of cyclogenesis in the world, is largely responsible for the winter weather regime of the Port.

The location of Nice near the eastern limit of the area normally affected by Mistral winds reduces the impact of the Mistral, when compared to ports farther west, such as Toulon or Marseille. If surface Mistral winds do reach as far eastward as Nice, they are limited to about force 6 (22-27 kt). The anchorage outside the protective confines of the harbor breakwaters is exposed and vulnerable however, and occasionally experiences westerly (280°) Mistral winds to 40 kt or more accompanied by southwesterly waves with heights of 6 ft (2 m) or greater. Maximum occurrence is in late winter/early spring. In those instances when northerly Mistral winds reach as far eastward as Nice, they seldom are felt at the surface in the protected Port area because of the barrier provided by the mountains north of Nice. Above the 600-1000 ft (183-305 m) level however, the wind force is quite strong, causing a strong vertical wind shear to develop in the lower levels of the atmosphere and creating hazardous landing conditions at the Nice airport. Although no specific information is available for Nice, the adjacent Port of Villefranche infrequently experiences northwesterly winds of 35+ kt that usually last from 1 to 6 hours (1 to 2 hours is most common) as low pressure centers from central France move southeastward into the Gulf of Genoa. Because of the close proximity of the two ports, similar winds should be expected at Nice.

East to southeasterly winds cause the greatest problem at Nice. Usually accompanied by overcast, rainy weather, the wind generates waves which pass through the southeastward facing port entrance and enter the inner harbor. Small boating to/from the anchorage may be

adversely affected, as well as some moorings near the harbor entrance. Strong winds with an easterly component are usually caused by high pressure over central Europe and/or low pressure south or southwest of Nice.

Southerly winds and waves are rare, and are normally caused by depressions moving into the Ligurian Sea or across Corsica into Italy. The swell is generally more of a problem than the wind at the anchorage, but seldom exceeds 6 ft (2 m) with maximum heights of 10 ft (3 m). The swell may persist for 2 or 3 days, and arrive/persist after the wind changes direction. The result is a swell direction which is at an angle of 45° to 90° to the anchored vessels' longitudinal axis, causing the vessels to roll (Shaver, undated). The swell also makes the channel to the Port entrance difficult to navigate (FICEURLANT, 1984).

The most frequent wind direction in the early morning is northerly, becoming southeasterly or southwesterly in the afternoon. The mean wind speed during winter is about 7 kt, with little diurnal variation (Hydrographer of the Navy, 1965).

Precipitation is common, occurring on about 1/3 of the days during the season. Snow is an infrequent occurrence at Nice. One accumulation of 13 inches (about 33 cm) was recorded in 1956. Snow generating conditions result from overrunning caused by a cold high pressure cell north of Nice producing northeasterly flow while a warm low pressure system south of Nice produces moist southeasterly flow. The northeasterly wind is called "Lombarde."

Temperatures are moderate during winter. January, the coldest month, has mean maximum and minimum temperatures of 55°F (13°C) and 39°F (4°C) respectively, based on airport records. The lowest recorded temperature for a 17-year period was only 25°F (-4°C), but wind chill (temperature combined with wind) can be very cold. Table 3-1 can be used to determine wind chill for various temperature and wind combinations.

Table 3-1. Wind Chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"								
Knots	MPH	Temperature (°F)								
Calm	Calm	40	35	30	25	20	15	10	5	0
		Equivalent Chill Temperature								
3-6	5	35	30	25	20	15	10	5	0	-5
7-10	10	30	20	15	10	5	0	-10	-15	-20
11-15	15	25	15	10	0	-5	-10	-20	-25	-30
16-19	20	20	10	5	0	-10	-15	-25	-30	-35
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55

B. Spring (March through May)

According to Brody and Nestor (1980), springtime weather in the Nice area is characterized by periods of stormy winter-type weather alternating with false starts of more settled summer-type weather. Mistral events still affect the anchorage until late in the season but become weaker and less frequent after March, and rare by the end of May.

Easterly through southerly winds and swell can be expected for short periods early in the season as extra-tropical storm systems transit the area, but occur with decreasing frequency after March. March is the wettest month of the season, with an average of 3.5 inches (90 mm). Precipitation amounts decrease through the remainder of the season. Occasional thunderstorms are recorded during periods of rainy weather but are usually not severe.

Temperatures warm significantly during the season, with a mean daily maximum of 70°F (21°C) being normal for May. Mean minimum temperatures for the same month average 55°F (13°C).

C. Summer (June through September)

By summer, the extratropical storm track has moved north of the Mediterranean Basin, so extratropical cyclones and associated wind and inclement weather are not common; generally settled weather conditions prevail

at Nice. Precipitation is at its yearly minimum, with an average of only 3/4 inch (19 mm) recorded during July. Early morning winds are mostly calm until September, during which light northerly winds prevail. Afternoon winds are mostly southeast through southwest (sea breeze). The mean daily maximum temperature for July and August, the warmest months, is about 81°F (27°C). Mean minimum temperatures for the same months average about 66°F (19°C).

D. <u>Autumn (October)</u>

The short autumn season at Nice usually lasts for the single month of October. As is the case for most of the region, it is characterized by an abrupt change to winter-type weather (Brody and Nestor, 1980).

The extratropical storm track returns from northern Europe to the Mediterranean Basin, allowing eastward-moving extratropical storms to once again bring unsettled conditions to Nice. Gusty winds with increased wave heights become more frequent. October is the wettest month of the year at Nice, with an average accumulation of 5.1 inches (130 mm) during the month. Occasional thunderstorms may occur during rainy periods.

Temperatures decrease from the warm readings of summer, but wind chill is usually not a problem until winter.

3.6 Harbor Protection

The inner harbor of the Port of Nice is well protected from the effects of most wind and wave conditions, but as detailed below, portions of the inner harbor and the anchorage are exposed and vulnerable to some conditions.

3.6.1 Wind and Weather

Wind alone has only minor effects on harbor operations. The topography of the landmass west, north, and east effectively blocks most wind except winds from

east-southeast clockwise through west-southwest. Even a strong Mistral event which extends as far eastward as Nice has only minimal impact on the inner harbor. On many occasions light easterlies are reported at Nice when strong northwesterlies are blowing at Marseille. When a strong Mistral event is occurring at Marseille the wind at Nice may vary over a wide range. Most often at 0600L it is north-northwesterly 6 to 10 kt and, at 1800L calm (Hydrographer of the Navy, 1965).

While the light winds are occurring in the inner harbor however, strong westerly winds to 40 kt or higher may be observed at the anchorage and even stronger 2-3 n mi offshore. Likewise, while the wind may be light at the surface, strong northerly winds may be blowing at 600-1000 ft (183-305 m) above the ground, creating a strong vertical wind shear which makes aircraft landing conditions at the Nice airport extremely hazardous.

February and March, two of the windiest months, each have an average of 6 days with wind speeds ≥32 kt. During these same months, the mean wind speed is only 6 kt during early morning and 8 kt during early afternoon (Hydrographer of the Navy, 1965).

Winds from the south quadrant strike the Port area essentially unimpeded, but fortunately such conditions are not common, and cause only minor problems in the inner harbor.

3.6.2 Waves

Except for waves from the southeast quadrant, the inner harbor is well protected from wave motion. But since the harbor entrance is open to the southeast, waves from that quadrant affect inner harbor operations. Vessels moored in the 2 outermost basins, Avant Port and Bassin du Commerce, may be subject to shifting due to wave motion, with vessels in Bassin des Amiraux are only slightly at risk. Those ships moored in Bassin Lympia, the innermost basin, should not be affected.

For those ships that anchor out rather than enter the inner harbor, the most significant impact would be the inability of small boats to make runs to/from the inner harbor due to hazardous wave conditions in the harbor entrance.

3.7 Protective and Mitigating Measures

3.7.1 Sortie/Move to a New Anchorage

Because of the exposure of the anchorage to winds and waves from east-southeast to west-southwest, vessels are advised to move to a more protected anchorage if heavy weather conditions are forecast. While the ships may be able to remain at anchor without significant difficulty, small boat runs to/from the inner harbor may not be feasible. The adjacent Port of Villefranche should be considered, as well as the Ports of Marseille, Toulon, or Cannes depending on wind direction.

3.7.2 Sortie/Remain in Inner Harbor

Because of the protection afforded to most of the inner harbor by the breakwater, ships should be able to remain in the harbor without significant risk. Strong winds may require that mooring lines be doubled.

3.7.3 Scheduling

Afternoon (1300L) winds have a higher mean speed during every month of the year than do those observed during early morning (0700L). The difference is only 1 or 2 kt during the winter months, increasing to 5 or 6 kt by late spring and early summer, indicating a definite sea breeze effect. Consequently, during the months of April through October, evolutions requiring light or calm winds should be scheduled during early morning hours.

3.8 Local Indicators of Hazardous Weather Conditions

The Port of Nice is located near the eastern limit of the area experiencing the Mistral, so when Mistral winds do reach the Port, they are weak as compared to those experienced farther west along the coast.

The following guidelines have been extracted from various sources and are intended to provide the insight necessary to enable the meteorologist to better understand the various phenomena that affect the Port of Nice. Because Nice is not in an area normally subjected to wind during an initial Mistral onset, most of the more technical guidelines for Mistrals have been omitted from this listing. If a more comprehensive list is desired, the reader is referred to section 3.8 of the port studies of either Marseille or Toulon, France.

3.8.1 Mistral

1. For Mistral winds to affect the Villefranche-Nice area, they will first be observed at Marseille and Toulon. Alongshore pressure gradient with higher pressure to the west, is important in predicting Mistral extent. When a 10 mb difference exists between Toulon and Nice, the Mistral will spread eastward. With only a 2 mb difference between Marseille and Toulon, the Mistral will cease near Toulon.

2. Eastward from Iles d'Hyères there is a rapid decrease in the frequency and force of the Mistral. It blows at times all along this coast but because of its reduced frequency and intensity it is not the same threat as around the Rhône delta. The general climate of the French Riviera benefits from being sheltered from the most intense form of Mistral which is experienced farther west. Often light easterlies are reported at Nice when strong northwesterlies are reported at Marseille (Hydrographer of the Navy, 1965).

3. The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy (Brody and Nestor, 1980).

4. Conditions which favor the formation of a Genoa low are conducive to the start of a Mistral at Marseille. A strong Mistral at Marseille may spread eastward to the coastal waters near Nice and Villefranche.

5. The Mistral will start at Marseille when one (or more) of three surface pressure differences is achieved: Perpignan-Marseille, 3 mb; Marseille-Nice, 3 mb; or Perpignan-Nice, 6 mb. Such differences usually develops within 24 hr after a closed Genoa low appears, but it occasionally occurs earlier (Brody and Nestor, 1980).

6. Associated Weather - When fully established, the Mistral is usually accompanied by clear skies. However, rain (or in winter, rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral (Hydrographer of the Navy, 1965). Skies along the coast are usually clear. Precipitation is uncommon, except when the Mistral is shallow with a southerly flow at mid-levels causing middle clouds and rain. Other exceptions are at the cold front associated with the onset of the Mistral and at secondary cold fronts associated with reintensification of Mistral conditions. However, as the cold air moves out over the warmer water, convective cloudiness increases.

7. If a Mistral is occurring at Marseille while light winds are observed at Villefranche/Nice, wind shear in the lower levels of the atmosphere may create hazardous landing conditions at the Nice airport.

.2 Non - Mistral

1. A well defined low pressure center that moves southeastward into the Gulf of Genoa from central France may initiate Mistral onset farther west. See guideline 3.8.1.1 above.

2. The early stages of lee cyclogenesis south of the Alps commonly result in southwesterly 30-40 kt winds in the region between the southern French Coast and Corsica (Brody and Nestor, 1980).

3. Poorest visibility tends to occur during spring and early summer but visibility restriction is seldom a problem.

3.9 Summary of Problems, Actions, and Indicators

Table 3-2 is intended to provide easy to use seasonal references for meteorologists on ships using the Port of Nice. Table 2-1 (section 2) summarizes Table 3-2 and is intended primarily for use by ship captains.

Table 3-2. Potential problem situations at Port of Nice - ALL SEASONS

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
1. Moored-inner harbor. Strongest in Winter & early Spring Uncommon in Summer Also occurs in Autumn	a. E-SE'ly waves - E'ly winds produce the greatest problem at Nice. Caused by high pressure over central Europe and/or low pressure south or southwest of Nice. Creates waves which pass through entrance to inner harbor. Usually accompanied by cloudy, rainy weather.	a. Waves may cause vessels moored near Port entrance to move excessively or shift at their berth. Additional mooring lines or doubling of mooring lines may be required. Be aware of wind chill factor.	a. A strong or strengthening high pressure cell over central Europe with a low pressure center south or southwest of the French Riviera can create the wind flow which results in the E-SE'ly waves at Nice.
2. Anchored. Strongest in Winter & early Spring Uncommon in Summer Also occurs in Autumn	a. E-SE'ly wind/waves - E'ly winds create the greatest problems at Nice. Caused by high pressure over central Europe and/or low pressure south or southwest of Nice. The anchorage is exposed to the full force of the wind and waves. Usually accompanied by cloudy, rainy weather.	a. The most adverse impact is limited to small boat operations to/from the anchorage as discussed in section 4.a below. A particularly strong event may require the deployment of 2 anchors, but if such an event is forecast, vessels should consider moving to the more protected anchorage at Villefranche. Be aware of wind chill factor.	a. A strong or strengthening high pressure cell over central Europe with low pressure center south or southwest of the French Riviera can create the wind/waves at Nice.
Occurs mainly in Winter, Spring, and Autumn Uncommon in Summer	b. S-SW'ly wind/waves - Uncommon at Nice, but can result from depressions moving into the Ligurian Sea or across Corsica into Italy or in the early stages of cyclogenesis south of the Alps. Swell seldom exceeds 6 ft (2 m) but may reach 10 ft (3 m) and persist for 2-3 days. The swell may arrive/persist after the wind changes direction, resulting in a swell direction 45°-90° to the wind direction which causes anchored vessels to roll.	b. The most adverse impact is limited to small boat operations to/from the anchorage as discussed in section 4.b below. The deployment of 2 anchors may be required, but considering the potential size and persistence of the winds and waves, a sortie to a more protected anchorage, such as Toulon, should be considered. Villefranche will likely experience the same conditions as Nice.	b. The early stages of cyclogenesis south of the Alps commonly result in SW'ly 30-40 kt winds in the region between the south French coast and Corsica. S'ly (160° to 220°) winds and swell can be caused by depressions moving into the Ligurian Sea or across Corsica into Italy. Swell waves seldom exceed 6 ft (2 m), but on rare occasions will reach 10 ft (3 m).
Strongest in late Winter & early Spring Uncommon in Summer Also occurs in Autumn	c. Mistral wind/waves - W to NW'ly wind common in Marseille/Toulon and over Gulf of Lion. Occasionally spreads eastward to Nice area. Most common in late winter/early spring. Anchorage may experience W'ly winds of 40+ kt and SW'ly waves of 6+ ft (2 m).	c. Ships in the anchorage should experience only minor problems but the wind force may require the use of a second anchor. As discussed in section 4.c below, small boat runs to/from the anchorage may be impacted. The roadstead at Villefranche may offer more protection.	c. Although the Mistral causes only minimal problems in the anchorage, it is prudent to be aware of forthcoming Mistral events. (1) Conditions which favor the formation of a Genoa low are conducive to the start of a Mistral at Marseille, and a strong Mistral may spread eastward to the coastal waters near Nice. (2) The Mistral will start at Marseille when one of three pressure differences is achieved (western most point has highest pressure): Perpignan - Marseille, 3 mb; Marseille - Nice, 3 mb, or Perpignan - Nice, 6 mb. Such differences usually develops within 24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (3) There is a rapid decrease in the frequency and average force of the Mistral east of Iles d' Hyères. On many occasions light E'lys are reported at Nice when strong NW'lys are blowing at Marseille. (4) For Mistral winds to affect Nice/Villefranche, they must first be observed at Marseille/Toulon. Alongshore pressure gradient is important in predicting Mistral extent. When a 10 mb difference exists between Toulon and Nice, the Mistral will spread eastward. With only a 2 mb difference between Marseille and Toulon the Mistral will stop near Toulon. (5) The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy. (6) When fully established the Mistral is usually accompanied by clear skies. However, rain (or, in winter, rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral.

Table 3-2. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
3. Arriving/departing. Strongest in Winter & early Spring Uncommon in Summer Also occurs in Autumn	a. E-SE'ly winds/waves - E'ly winds/waves create the greatest problem at Nice. Caused by high pressure over central Europe and/or low pressure south or southwest of Nice. Creates a swell which passes through entrance to inner harbor as well as impacting the anchorage. Usually accompanied by cloudy, rainy weather.	a. Arriving ships should be aware of potential wave action at Port entrance and possible curtailment of boat runs to/from the anchorage. Be aware of wind chill factor.	a. A strong or strengthening high pressure cell over central Europe with low pressure center south or southwest of the French Riviera can create the wind/waves at Nice.
Occurs mainly in Winter, Spring, and Autumn Uncommon in Summer	b. S-SW'ly wind/waves - Uncommon at Nice, but can result from depressions moving into the Ligurian Sea or across Corsica into Italy or in the early stages of cyclogenesis south of the Alps. Swell seldom exceeds 6 ft (2 m) but may reach 10 ft (3 m) and persist for 2-3 days. The swell may arrive/persist after the wind changes direction, resulting in a swell direction that is 45°-90° to the wind direction which causes anchored vessels to roll. The swell can also make the channel leading to the inner harbor entrance difficult to navigate.	b. Arriving ships should be aware of possible rolling at anchor caused by varying wind and swell directions, possible curtailment of boat runs to/from the anchorage, and the potential difficult navigation situation that may be encountered in the channel to the inner harbor.	b. The early stages of cyclogenesis south of the Alps commonly result in SW'ly 30-40 kt winds in the region between the south French coast and Corsica. S'ly (160° to 220°) winds and swell can be caused by depressions moving into the Ligurian Sea or across Corsica into Italy. Swell waves seldom exceed 6 ft (2 m), but on rare occasions will reach 10 ft (3 m).
Strongest in late Winter & early Spring Uncommon in Summer Also occurs in Autumn	c. Mistral wind/waves - W to NW'ly wind common in Marseille/Toulon and over Gulf of Lion. Occasionally spreads eastward to Nice area. Most common in late winter/early spring. Anchorage may experience W'ly winds of 40+ kt and SW'ly waves of 6+ ft (2 m). Inner harbor normally not affected.	c. Arriving and departing vessels should be aware of the tendency for wind to decrease markedly near shore while winds only 2-3 n mi offshore are blowing strongly.	c. The Mistral causes only minimal problems in the anchorage, but it often blows quite strongly close to the coast--the area inbound and outbound ships must transit when approaching or departing Nice. It is therefore prudent to be aware of forthcoming Mistral events. (1) Conditions which favor the formation of a Genoa low are conducive to the start of a Mistral at Marseille, and a strong Mistral may spread eastward to the coastal waters near Nice. (2) The Mistral will start at Marseille when one of three pressure differences is achieved (western most point has highest pressure): Perpignan - Marseille, 3 mb; Marseille - Nice, 3 mb, or Perpignan - Nice, 6 mb. Such differences usually develops within 24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (3) There is a rapid decrease in the frequency and average force of the Mistral east of Iles d' Hyères. On many occasions light E'lys are reported at Nice when strong NW'lys are blowing at Marseille. (4) For Mistral winds to affect Nice/Villefranche, they must first be observed at Marseille/Toulon. Alongshore pressure gradient is important in predicting Mistral extent. When a 10 mb difference exists between Toulon and Nice, the Mistral will spread eastward. With only a 2 mb difference between Marseille and Toulon the Mistral will stop near Toulon. (5) The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy. (6) When fully established the Mistral is usually accompanied by clear skies. However, rain (or, in winter, rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral.

[redacted]

Table 3-2. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
4., Small boats. Strongest in Winter & early Spring Uncommon in Summer Also occurs in Autumn	a. E-SE'ly wind/waves - E'ly winds/waves create the greatest problem at Nice. Caused by high pressure over central Europe and/or low pressure south or southwest of Nice. Creates a swell which passes through SE facing harbor entrance, making small boat runs to/from the anchorage hazardous. Usually accompanied by overcast, rainy weather.	a. While small boat operations in the inner harbor should not be strongly affected, swell entering the harbor entrance can make boat runs to/from the anchorage very hazardous if not impossible. Small boat operations outside the inner harbor may need to be suspended until conditions abate. Be aware of wind chill factor.	a. A strong or strengthening high pressure cell over central Europe with low pressure center south or southwest of the French Riviera can create the wind/waves at Nice.
Occurs mainly in Winter, Spring, and Autumn Uncommon in Summer	b. S-SW'ly wind/waves - Uncommon at Nice, but can result from depressions moving into the Ligurian Sea or across Corsica into Italy or in the early stages of cyclogenesis south of the Alps. Swell seldom exceeds 6 ft (2 m) but may reach 10 ft (3 m) and persist for 2-3 days, making small boat runs to/from the anchorage hazardous.	b. Small boat operations in the inner harbor are largely unaffected, but wind/wave conditions outside the breakwater may preclude small boat operations to/from the anchorage until conditions abate.	b. The early stages of cyclogenesis south of the Alps commonly result in SW'ly 30-40 kt winds in the region between the south French coast and Corsica. S'ly (160° to 220°) winds and swell can be caused by depressions moving into the Ligurian Sea or across Corsica into Italy. Swell waves seldom exceed 6 ft (2 m), but on rare occasions will reach 10 ft (3 m).
Strongest in late Winter & early Spring Uncommon in Summer Also occurs in Autumn	c. Mistral wind/waves - W to NW'ly wind common in Marseille/Toulon and over the Gulf of Lion. Occasionally spreads eastward to Nice area. Most common in late winter/early spring. Anchorage may experience W'ly winds of 40+ kt and SW'ly waves of 6+ ft (2 m), making small boat runs to/from the anchorage hazardous.	c. Small boat operations in the inner harbor are largely unaffected, but the wind/wave conditions at the anchorage may preclude small boat operations to/from the anchorage until conditions abate.	c. Although the Mistral causes only minimal problems for ships in the anchorage, it can cause great difficulty for small boats attempting to make runs to/from the anchorage. It is therefore prudent to be aware of forthcoming Mistral events. (1) Conditions which favor the formation of a Genoa low are conducive to the start of a Mistral at Marseille, and a strong Mistral may spread eastward to the coastal waters near Nice. (2) The Mistral will start at Marseille when one of three pressure differences is achieved (western most point has highest pressure): Perpignan - Marseille, 3 mb; Marseille - Nice, 3 mb, or Perpignan - Nice, 6 mb. Such differences usually develops within 24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (3) There is a rapid decrease in the frequency and average force of the Mistral east of Iles d' Hyères. On many occasions light E'lys are reported at Nice when strong NW'lys are blowing at Marseille. (4) For Mistral winds to affect Nice/Villefranche, they must first be observed at Marseille/Toulon. Alongshore pressure gradient is important in predicting Mistral extent. When a 10 mb difference exists between Toulon and Nice, the Mistral will spread eastward. With only a 2 mb difference between Marseille and Toulon the Mistral will stop near Toulon. (5) The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy. (6) When fully established the Mistral is usually accompanied by clear skies. However, rain (or, in winter, rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral.
5. Aircraft operation. Strongest in late Winter & early Spring Uncommon in Summer Also occurs in Autumn	a. Mistral winds - A strong outbreak of the W to NW'ly Mistral winds common in Marseille/Toulon may occasionally spread eastward to Nice area. Due to the mountains north of Nice, they are usually observed as strong NW'ly winds at 600 to 1000 ft (183-305 m) above the surface while surface winds remain light, frequently in a direction opposing the Mistral flow. The result is a strong vertical wind shear in the lower levels of the atmosphere over the Nice airport.	a. Aircraft operations at or near the Nice airport may be subject to severe/ extreme turbulence in the vicinity of the wind shear. Only critically urgent flights that are fully briefed on the potential hazard should be conducted when the wind shear conditions exist.	a. Because of the danger that the low level wind shear can present to aircraft using the Nice airport, it is prudent to be aware of forthcoming Mistral events. (1) Conditions which favor the formation of a Genoa low are conducive to the start of a Mistral at Marseille, and a strong Mistral may spread eastward to the coastal waters near Nice. (2) The Mistral will start at Marseille when one of three pressure differences is achieved (western most point has highest pressure): Perpignan - Marseille, 3 mb; Marseille - Nice, 3 mb, or Perpignan - Nice, 6 mb. Such differences usually develops within 24 hr after a closed Genoa low appears, but it occasionally occurs earlier. (3) There is a rapid decrease in the frequency and average force of the Mistral east of Iles d' Hyères. On many occasions light E'lys are reported at Nice when strong NW'lys are blowing at Marseille. (4) For Mistral winds to affect Nice/Villefranche, they must first be observed at Marseille/Toulon. Alongshore pressure gradient is important in predicting Mistral extent. When a 10 mb difference exists between Toulon and Nice, the Mistral will spread eastward. With only a 2 mb difference between Marseille and Toulon, the Mistral will stop near Toulon. (5) The eastern boundary of the Mistral extends downwind from the western edge of the Alps through San Remo, Italy. (6) When fully established the Mistral is usually accompanied by clear skies. However, rain (or, in winter, rain and/or snow) and violent squalls commonly accompany the cold front which precedes the Mistral.

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PORT VISIT INFORMATION

JUNE 1986. NEPRF meteorologists R. Fett and R. Picard met with the Acting Port Captain and the Chief Forecaster to obtain much of the information included in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always

present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period ($f = 1/T$) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining

frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \tag{1.2}$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \tag{1.3}$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \tag{1.4}$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing

lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) (hrs)	Sig Wave (H1/3) Period/Height (sec) (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water

conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

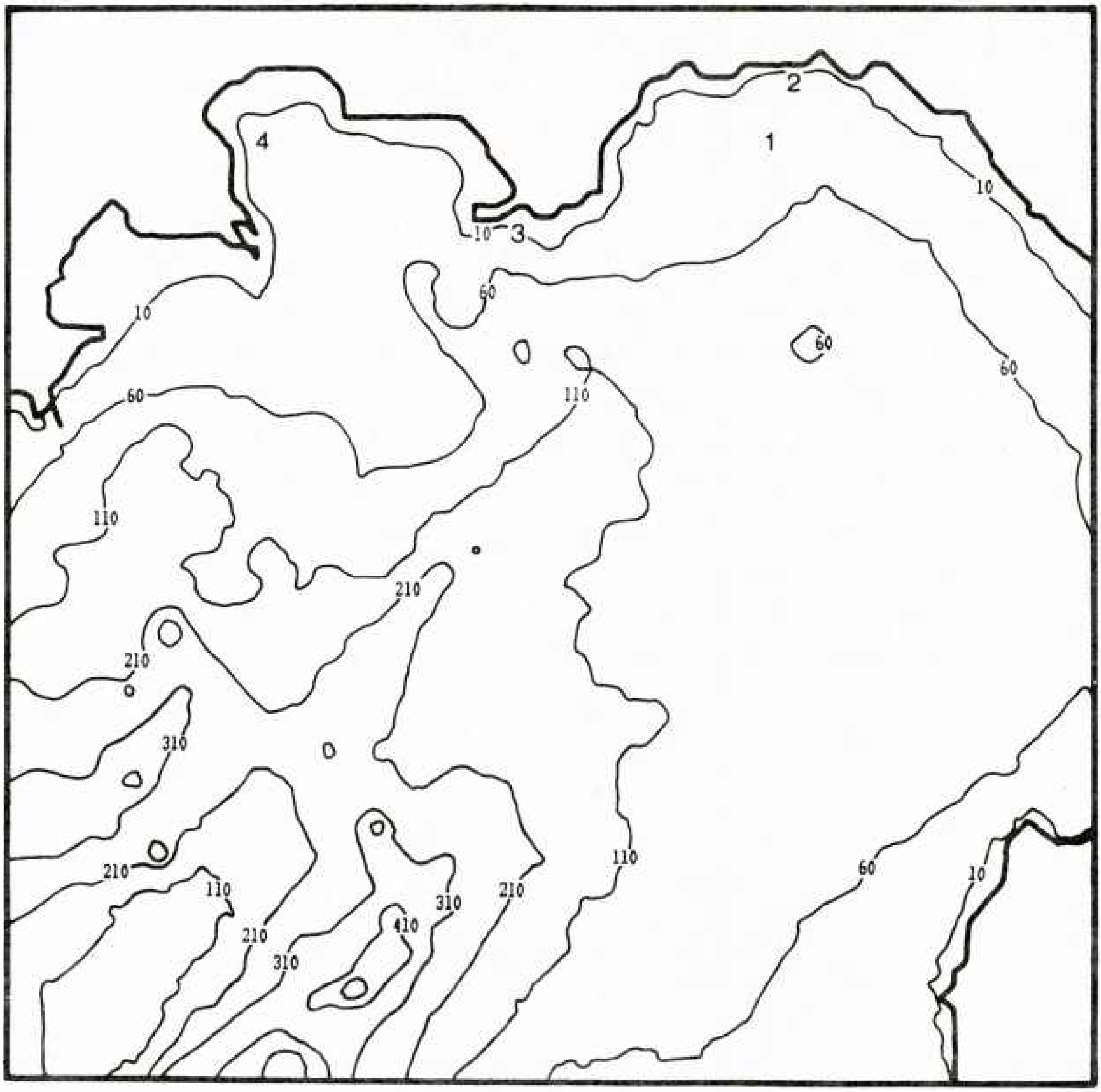

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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